Construction of a Safety Supervision System for Low-Altitude Economy based on Risk Prevention and Control

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Abstract: China's low-altitude economy exceeded 500 billion yuan in 2023, especially with unmanned aircraft represented by eVTOL becoming a new engine for China's economic growth. In the face of new things, there are deficiencies in the corresponding institutional norms at present. The current airspace coordination management system is rigid, approval procedures are cumbersome, and coordination is difficult. How to scientifically plan and coordinate airspace resources urgently needs to be addressed; In terms of airworthiness certification, there is a lack of unified standards, and there is an urgent need to improve the airworthiness standards and certification system. In addition, in the face of the risk of drone infringement, supervision is difficult. It is necessary to enhance the security of drones, actively explore solutions, and promote the sustained and healthy development of China's low-altitude economic form.

Keywords: Low Altitude Economy; eVTOL; Airspace Management; Airworthiness Certification; Safety Supervision

1. Introduction

As a new engine of China's economic growth, the low-altitude economy is a typical representative of new quality productivity, a strategic emerging industry, and a frontier direction leading future industries, opening up new horizons for further high-quality economic development. The concept of the low-altitude economy was first proposed in the Outline of the National Integrated Three-Dimensional Transport Network in 2021, which is of landmark significance. The 2023 Central Economic Work Conference emphasized the development of several strategic emerging industries such as biomanufacturing, commercial aerospace, and low-altitude economy. In 2024, the low-altitude economy was written into the government work report for the first time. These documents all suggest that the low-altitude economy is gradually becoming a new growth point. This article reviews the laws and regulations related to the low-altitude economy, analyzes the current situation and shortcomings of the development of the low-altitude economy in China, and proposes countermeasures to promote the high-quality development of the low-altitude economy, providing reference and guidance for the development of the low-altitude economy in China.

2. Overview of the Low-Altitude Economy

2.1 The Scope and Development Status of the Low-Altitude Economy

At present, there is no unified concept of the low-altitude economy in the academic circle. The Shenzhen Special Economic Zone Low-altitude Economy Industry Promotion Regulations define the low-altitude economy: It is a comprehensive economic form that is driven by low-altitude flight activities of civil manned aircraft and unmanned aircraft, radiating and driving the integrated development of industries in areas such as aircraft research and development, production and sales, as well as infrastructure construction and operation, flight support and derivative comprehensive services related to low-altitude flight activities. As the concept suggests, the low-altitude economy is a new type of comprehensive economic concept, consisting of four parts: low-altitude manufacturing, low-altitude flight, low-altitude support and comprehensive services. Different from the low-altitude industry, the low-altitude industry belongs to the broad concept of the low-altitude economy, and enterprises involved in the upstream, midstream and downstream of the low-altitude

economy that provide market-based products and services all belong to the low-altitude industry; The low-altitude economy also includes public sectors such as the government that coordinate and manage low-altitude flight activities, as well as entities that provide non-marketized products and services [1].

The low-altitude economy is driven by various manned or unmanned aircraft, represented by electric vertical take-off and landing aircraft (eVTOL). At present, the development of eVTOL has attracted traditional aviation giants Boeing and Airbus, as well as automakers such as Mercedes-Benz, Hyundai and Geely, and some Internet companies have begun to lay out the eVTOL track in order to seize the high ground of advanced urban transportation in the future. Ehang's self-developed EH216-S unmanned aircraft has obtained the world's first standard test flight permit and completed its maiden flight in Shanghai, a milestone event indicating that its design, manufacturing, quality system, and production management of aircraft products have been recognized by the Civil Aviation Administration of China and meet the operational requirements for commercial flights. It also demonstrates China's leading position globally in the marketization of unmanned aircraft.

3. Risk Analysis of the Low-Altitude Economy

3.1 Airspace Management Risks

3.1.1 The problem of tight airspace resources

"Low altitude" is by no means a mechanical concept; its connotation changes with economic and social development. In 2010, the "Opinions on Deepening the Reform of Low-altitude Airspace Management in China" stated that low-altitude airspace is, in principle, below 1,000 meters of true altitude, and each region can specifically demarcate it based on actual needs and implement it after approval. The "Guiding Opinions on Promoting the Development of the General Aviation Industry" issued in 2016 further scientifically planned the airspace, achieving seamless connection between surveillance airspace and reporting airspace below 3000 meters of true height, facilitating the maneuvering of general aviation aircraft. In 2023, the Civil Aviation Administration of China (CAAC) released the Basic Classification Method of National Airspace, dividing the national airspace into seven categories, namely A, B, C, D, E, G and W, based on flight rules and airspace environment. Among them, G and W are non-controlled airspace and are currently the main flight areas for low-altitude aircraft. The G-class airspace is divided into the airspace below 300 meters in true altitude, excluding the B-class and C-class airspace, and the airspace below 6,000 meters in average altitude, which has no impact on civil aviation public flights. This section is mainly applicable to manned aircraft. The W airspace is only designated in the part of the G airspace that is less than 120 meters in true height, allowing small unmanned aircraft to fly, and eVTOL to fly within the G and W airspace. Despite the country's vigorous promotion of airspace pilot reforms, the available low-altitude airspace for civilian use remains limited at present. With the development of general aviation, there will be an explosive growth in the number of unmanned aerial vehicles (UAVs). In 2022, the number of civilian UAVs registered in China reached 958,000, up 15.14 percent year-on-year. In addition, the commercial application of the "low altitude economy +" model has also reduced airspace to some extent. For example, in developed agricultural areas, a large number of agricultural drones are used for sowing, fertilizing, testing and plant protection operations, making the relevant airspace tighter.

3.1.2 Difficult to manage and coordinate

According to the "Basic Rules of Flight of the People's Republic of China", flight control within the territory shall be uniformly organized and implemented by the Air Force of the People's Liberation Army of China. Relevant flight control departments shall implement air traffic control in accordance with their respective duties. From this, it can be known that the civil aviation department is responsible for the air routes and the airspace around civil airports in our country, while the other airspace is approved by the military. At present, the organizational structure of airspace management in our country is centered around the National Air Traffic Control Commission. Under the unified leadership of the National Air Traffic Control Commission, the military and civil aviation are managed hierarchically respectively. Civil

aviation is responsible for air traffic control within the scope of civil aviation, the military provides flight services for military flights, and regional air traffic control coordination committees at all levels manage national air traffic, provide national civil aviation air traffic control, and monitor the operation of the national civil aviation air traffic control system. In terms of low-altitude airspace applications, the airspace user first submits the application to the civil aviation department. After the civil aviation unit reviews the applicant's qualifications, it is transferred to the military air traffic control department for approval. The air traffic control department then transfers it to the relevant responsible units for approval according to different usage items. Therefore, one airspace application often involves multiple control units [2]. In general, the military is in a dominant position in airspace management, which is in line with the defensive strategy that our country has long maintained since the founding of the People's Republic of China. Due to the weakness of air power in the early days of the founding of the country, the airspace should prioritize military flights and safeguard national defense security, and this management design has played a positive role. But in the current context of fundamental changes in the international balance of power and the growing demand for general aviation, airspace resources have become increasingly precious. The current airspace management system is rigid, approval procedures are cumbersome and complex, and there is no way to seek relief, which severely restricts the healthy development of China's low-altitude economy. Unlike China, the United States has a joint military and civilian navigation system. In 1958, the Federal Aviation Act transferred the safety supervision responsibilities of the Civil Aviation Commission (CAB) to the Federal Aviation Administration (FAA), and gave it full authority to manage the military-civilian joint system for air navigation and traffic control. The act established the FAA's central position in airspace management and its responsibility to coordinate the use of military-civilian airspace. When designating airspace, the FAA needs to coordinate military and civilian demands and formulate rules for airspace use. For the military, it is necessary to complete military tasks such as military operations, exercises and training, and ensure the safety and confidentiality of military flights. In terms of civil aviation, to meet the growing demand for both civil and general aviation and to complete logistics and transportation tasks, the FAA needs to improve the efficiency of airspace utilization as much as possible. In contrast, the airspace management mechanism in the United States is more mature.

3.2 Airworthiness Standards and Certification Challenges

Flight safety is the top priority in the design, manufacture and operation of aircraft. In recent years, the civil aircraft industry has developed particularly rapidly and has played an important role in the national economic development. Therefore, the issue of aircraft regulation needs to be addressed urgently. The development of airworthiness standards and the construction of airworthiness systems ensure the safety of low-altitude flights, regulate the market order and promote the development of the aviation industry. An airworthiness license is a certificate issued by the authority in accordance with the regulations on the certification of civil aircraft products and components, certifizing that the aircraft is in a safe and usable condition. According to Article 8 of the Interim Regulations on the Administration of Unmanned Aircraft Flight, the design, production, import, flight and maintenance of China's medium and large civil unmanned aircraft systems require airworthiness permits from the civil aviation authorities [3]. According to the supplementary provisions of this regulation, medium and large unmanned aircraft with a maximum takeoff weight of more than 25kg and urban advanced air transportation represented by eVTOL must obtain airworthiness permission. As a new thing, eVTOL is highly technical and complex in design. Compared with traditional manned aircraft, there is no consensus on airworthiness standards at present, and it is defined as a special category of aircraft for airworthiness certification. At present, the CAAC conducts eVTOL certification on a case-by-case basis, mainly referring to CCAR-23 (airworthiness standards for normal, practical, aerobatic and commuter aircraft), CCAR-27 (Standard for normal rotorcraft airworthiness) and the

SC-VTOL for vertical take-off and landing aircraft issued by the European Aviation Safety Agency (EASA). Article 92.301 of the Civil Unmanned Aircraft System Airworthiness Certification clearly states that airworthiness approval for unmanned aircraft requires obtaining three certificates: Type Certificate (TC), Production License (PC), and Airworthiness Certificate (AC). The type certificate is a certificate of conformity issued by CAAC for the design approval of civil aircraft and engines in accordance with CCAR-21 (Civil Aviation Products and Components Conformity Certification Regulations). The production license requires that the applicant has established a complete set of quality systems for the production of civil aircraft to ensure that every aircraft and component produced is in a safe and usable condition. An airworthiness certificate is when CAAC considers that the aircraft conforms to an approved design and is in a safe and available condition, which is a necessary condition for the operation of an aircraft. Of the three certificates, obtaining a type certificate is the most difficult. Take Ehang's EH216-S as an example. At the end of 2020, EHang submitted an application to the Civil Aviation Administration for a type certificate for the EH216-S manned unmanned aircraft. In January 2021, the Civil Aviation Administration of China accepted the application and formed a type certification review team to conduct the review. In 2022, the Civil Aviation Administration of China issued the Special Conditions for the EH216-S unmanned aircraft system, the world's first special conditions for the type approval of unmanned aircraft, marking a milestone in the eVTOL review. After three years, on October 13, 2023, the Civil Aviation Administration of China awarded EHang the type certificate for the EH216-S unmanned aircraft, the world's first eVTOL type certificate, setting an industry benchmark for global eVTOL airworthiness certification [4]. Compared with traditional manned aircraft, unmanned manned aircraft use a large number of innovative designs, lack experience and cases to draw upon, and currently there are no regulations for eVTOL airworthiness certification issued worldwide, which is a major challenge for the development of the low-altitude economy.

3.3 Risks of Drone Infringement

With the development of the low-altitude economy, there will surely be more aircraft flying over cities in the future. Taking smart drones as an example, with their flexibility and convenience, they can be combined with logistics, aerial photography, rescue and other fields, further opening up the civilian drone market, which also brings about private privacy and public safety issues. The most typical example is the "black flight" of drones, which refers to the act of flying drones in violation of laws and regulations such as the Basic Rules of Flight of the People's Republic of China, such as the operator taking off without obtaining the pilot qualification, taking off without applying for flight to the relevant authorities, and flying outside the approved airspace, altitude and time. In 2013, Qiao, Li and Hao, knowing they were not qualified to operate, privately operated model aircraft to take pictures of the terrain without applying for airspace from the civil aviation department, causing many civil aircraft to avoid them and resulting in significant damage to public property. The act of "unauthorized flights" not only endangers public safety, but also poses a great threat to China's national defense security by means of stealing footage, monitoring, etc. It may lead to the leakage of personal privacy in densely populated residential areas or areas with high population flow.

Drone infringement has certain particularities. First of all, micro and small drones have the characteristics of being small in size, low in noise and highly concealed. For example, the DJI Mini 4 Pro has strong image transmission capabilities, can take pictures of the environment 20 kilometers away, and performs stably in urban signal interference and occlusion environments. Therefore, when the operator commits an infringement, the victim often fails to detect the leakage of their privacy. Secondly, in drone infringement cases, the "human-machine separation" feature of the infringer and the drone, the distance between the infringer and the drone can reach tens of kilometers. Even if the victim discovers that their privacy rights have been infringed, it is often difficult to locate the infringer to seek relief. Again, drones have a wide range of signal frequency bands. For example, the 840.5-845 MHZ band is used for the uplink

remote control link of the drone, which receives signals from the remote control to complete various flight instructions. 1430-1444 MHZ is used for the downlink telemetry and information transmission link of the unmanned aerial vehicle (UAV) system, through which the operator can obtain information about the speed, position, altitude and battery level of the UAV at this time. Some drones use radio encryption communication technology, making it difficult for monitoring equipment to identify, monitor and track them. From this, it can be known that drone infringement is easier to carry out, less detectable, and more difficult to supervise than other forms of infringement. The pain point of drone infringement risks must be addressed.

4. Construction of Safety Supervision System under Risk Prevention and Control

4.1 Improve the Airspace Management System

4.1.1 Optimize the allocation of airspace resources

The division of airspace needs to take into account both the flight efficiency and flight safety of unmanned aerial vehicles simultaneously. Within the limited airspace, further detailed divisions are conducive to building a more complete and three-dimensional flight space structure. Drone flight modes can be divided into free airspace, layered airspace, radial airspace and tubular airspace. Free airspace is a completely unrestricted flight within the designated airspace, and the pilot can choose the most economical and convenient route. Layered airspace is the division of airspace into different levels based on altitude, with each level running different missions, performances, and models of aircraft. Radial airspace divides the airspace into straight or circular airspace, and aircraft can only travel within the designated airspace. Tubular airspace builds a fixed flight path, and drones lose all degrees of freedom. The control department can use several airspace division patterns at the same time based on factors such as traffic flow and airspace capacity. For logistics and food delivery drone routes, tubular airspace can be demarcated to ensure flight safety and efficiency. For low-altitude airspace with heavy traffic, radial routes can be demarcated and high-speed flight zones can be established. The European Single Sky Air Traffic Management Study (SESAR) vertically divides the low-altitude airspace into three categories: X, Y, and Z, allowing for drone recreational activities in the lower-risk low-altitude airspace and drone rescue and inspection operations in areas with special risks. A stratified, zoned and categorized airspace division model could be adopted to optimize the allocation of airspace resources and achieve the unity of safety and efficiency values.

At the same time, increasing the height of reporting airspace and unregulated airspace and expanding the range of low-altitude free airspace will create favorable conditions for the development of the general aviation industry. According to Sun Weiguo, director of the General Aviation Business Department and Unmanned Aerial Vehicle Working Committee of the China Air Transport Association, the Central Air Traffic Control Committee is about to carry out eVTOL pilot projects in Hefei, Hangzhou, Shenzhen, Suzhou, Chengdu and Chongqing. Authorizing the airspace below 600 meters of true altitude in the pilot document is an important measure to promote the development of the low-altitude economy. The increase in the upper limit of the reported airspace meets the vertical altitude requirements of different types of civil aircraft, such as light aircraft sightseeing flights and unmanned aerial vehicle photomapping, and is closer to the needs of life and market orientation, stimulating the vitality of market business innovation.

4.1.2 Establish a collaborative management mechanism

As a pilot demonstration area for low-altitude airspace, Sichuan has been actively promoting the reform of low-altitude airspace by virtue of its own aviation advantages. Since 2017, Sichuan has been actively promoting the pilot program of military-civilian integration of general aviation. It was approved as the first province in the country to pilot the collaborative management of low-altitude airspace and established the Office of the Sichuan Provincial Committee for Collaborative Management of Low-altitude Airspace, which is responsible for the coordinated management of airspace within its

jurisdiction, creating a new situation of military-civilian collaborative management. Unlike the previous military full authority management model, civil aircraft flying in the co-managed airspace only need to report a little before the flight, eliminating a large number of approval procedures and greatly improving the efficiency of airspace utilization. At present, the pilot airspace in Sichuan has expanded to over 7,800 square kilometers, forming a flight network that encircles Chengdu and connects the south and north of Sichuan. From point to area, it has achieved interconnection and interoperability, and the pilot results are beginning to show. Across the country, we can actively explore the integrated operation and management of military and civilian airspace, clarify the relationship between different administrative departments and local governments, actively coordinate local governments, air traffic control units and local military-civilian integration offices, establish military-civil aviation collaborative departments to uniformly manage and divide airspace resources while meeting the different needs of the military and civil aviation. In addition, we will continue to expand the area of low-altitude airspace reform and the area of low-altitude collaborative airspace. In the low-altitude coordinated airspace, we will actively promote the shift from controlled flight to low-altitude visual flight (VFR), allowing pilots to observe aircraft and ground obstacles on their own and carry out visual avoidance procedures to relieve the pressure on air traffic control departments and ensure the rational use of airspace [5]. We will continue to improve the construction of communication and navigation, high-tech facilities and services at airports and flight service stations (FSS), and manage and control low-altitude flying aircraft efficiently to achieve "visibility and control". Actively promote the low-altitude airspace reform model in Sichuan and other provinces, gradually transform the approval of low-altitude flights into a filing system, simplify the pre-flight procedures, formulate airspace management policies that are in line with local conditions and development plans, make full use of airspace, and continuously stimulate the enthusiasm and demand of the people for low-altitude flights.

4.2 Strengthen the Safety Supervision of Aircraft

4.2.1 Improve airworthiness standards and certification systems

At present, there is no unified system of regulations on airworthiness certification for civilian unmanned aircraft, represented by eVTOL, on a global scale. Due to the lack of airworthiness experience, the certification of unmanned aircraft in various countries is often conducted on a case-by-case basis and in a specialized manner. China, taking the EH216-S (multi-rotor) and V2000CG (compound wing) unmanned aerial vehicles that have obtained airworthiness certification as examples, have a higher dead weight and a simpler structure compared to tilt-wing unmanned aerial vehicles. In the future, more sophisticated and advanced aircraft will emerge, and it is necessary to quickly accumulate airworthiness experience, introduce special standards, and establish an airworthiness system for low-altitude aircraft. In 2019, EASA issued the SC-VTOL after reviewing a large number of eVTOL approval projects, making strict regulations on the airworthiness and operation of small manned aircraft. It is the world's first certification basis for eVTOL aircraft, but in practice, it has overly high requirements, resulting in huge costs and management pressure for enterprises. Promote the combination of top-level design and specialized certification, stipulate rough certification matters by issuing special conditions, insist on specialized certification for core matters of aircraft such as flight configuration and engine propulsion, further improve certification efficiency, quickly accumulate certification experience, improve certification rules, provide guidelines for enterprises' airworthiness, and promote the development of the low-altitude industry.

In addition, since the United States and Europe do not accept applications for civil unmanned aircraft airworthiness certification, there are differences in airworthiness certification between China and the United States and Europe. At present, the FAA of the United States and the EASA of Europe are accelerating their cooperation on airworthiness certification, making significant progress in the airworthiness certification of eVTOL. The two major civil aviation authorities are tending to unify their certification standards, which is

conducive to the formation of a global eVTOL market [6]. Under the framework of the International Civil Aviation Organization (ICAO), CAAC, FAA and EASA are all playing a key role in promoting the uniformity of global airworthiness standards, actively promoting cooperation through regular technical meetings, information sharing platforms, etc., avoiding differences caused by certification differences, and conducting airworthiness cooperation and mutual recognition. Develop more scientific and reasonable airworthiness standards to promote the unification of global airworthiness standards [7].

4.2.2 Enhance the security of unmanned aircraft

In order to reduce the potential safety risks of civil aircraft, the Ministry of Industry and Information Technology issued the Interim Measures for Radio Management of Civil Unmanned Aircraft, which detailed the management requirements and clarified the usage requirements of civil unmanned aircraft in different frequency bands. It strictly stipulates the radio frequency range and permission for different types of aircraft systems, which has strongly promoted the healthy and orderly development of civil unmanned aircraft [8]. At present, there is a lack of high-level legal support for privacy relief from the perspective of unmanned aircraft. Both laws, administrative regulations and rules are inadequate in protecting privacy rights. Article 14 of the Interim Measures for the Administration of Public Safety of Unmanned Aircraft in Hunan Province stipulates that "no unit or individual may use unmanned aircraft to spy on or take pictures of personal privacy." The Regulations on the Public safety Management of unmanned aircraft in Zhejiang Province explicitly prohibit the use of civilian unmanned aircraft for the act of peeping at or taking pictures of personal privacy. Although it objectively has a deterrent effect on privacy infringement by unmanned aircraft, it is still not strong enough compared to legal protection [9]. The author believes that provisions for protecting the privacy rights of drones should be incorporated into the Civil Aircraft Law. On this basis, the criminal law, civil law and related laws should make corresponding adjustments and add relevant provisions. At the same time, local governments can introduce specific adjustment details to further improve the regulatory system for unmanned aerial vehicles [10]. With the development of the low-altitude economy, the number of cases where civilian drones violate privacy rights will increase significantly in the future. The issue of "different judgments for the same case" of drone infringement can be effectively addressed by releasing guiding typical cases, filling legal loopholes and gaps, enhancing judicial credibility and maintaining judicial justice [11].

5. Conclusions

The low-altitude economy, as a representative of new quality productivity, has achieved some accomplishments at present, but the road ahead is still full of difficulties. We see governments and businesses taking many strategies and actions to address the challenges: airspace resources are releasing more development space under the coordinated management mechanism; The continuous improvement of airworthiness standards lays a solid foundation for the safe operation of civil aircraft; Drone security is being strengthened to regulate flight order and promote the healthy development of the low-altitude economy. In the future, with the continuous development of science and technology, the low-altitude economy is expected to make a qualitative leap and become an important part of China's economic development. We need to keep a close eye on the development of the low-altitude economy and constantly optimize our strategies to welcome the new era of vigorous development of the low-altitude economy.

Acknowledgments

Though the path of learning is hard, it is full of warmth because of the help of many people. In the future, with this gratitude, I will continue to delve deeper into the field of law, giving back to society with solid professional skills and living up to the teachings of my teachers and the expectations of my family.

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